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ABSTRACT

This document reports an experiment designed to assess the effects of learner control over the level of challenge in computer-assisted instruction (CAI) and collect data that will guide the design of future learner control experiments. The subjects were 78 undergraduate students in the College of Education at a large public university. The CAI included a simulation of an aviation instrument and taught subjects how to locate an aircraft's position in space by interpreting a complex display. Instructional research has not yielded the empirical information necessary to develop prescriptions for employing learner control features in this type of CAI. Three treatments that varied the subject's control over the level of challenge were compared: learner control, computer control, and learner control with advisement. Results indicated that learner control did affect subjects' time on task on an immediate test, but this effect appeared to be temporary. The change in time on task was probably caused by the way subjects adjusted their challenge level. Subjects who received advisement tended to set challenge levels higher and adjusted the challenge more frequently. One table and three figures are appended. (12 references) (Author/BBM)

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Title:

Learner Control versus Computer Control in Instructional Simulation

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Abstract

This experiment was designed to assess the effects of learner control over level of challenge in computer-assisted instruction (CAI) and collect data that will guide the design of future learner control experiments. The CAI included a simulation of an aviation instrument and taught subjects how to locate an aircraft's position in space by interpreting a complex display. Instructional research has not yielded empirical information necessary to develop prescriptions for employing learner control features in this type of CAI. Three treatments that varied the subject's control over level of challenge were compared: learner control, computer control, and learner control with advisement. Results indicated that learner control did affect subjects' time on task on an immediate test, but this effect appeared to be temporary. The change in time on task was likely caused by the way subjects adjusted their challenge level. Subjects who received advisement tended to set challenge levels higher and adjusted challenge more frequently.

LEARNER CONTROL VERSUS COMPUTER CONTROL IN INSTRUCTIONAL SIMULATION

State-of-the-art computer-assisted instruction (CAI) authoring systems enable instructional developers to assign control to learners or use a program to automatically control a variety of instructional components including lesson pace, sequence, feedback, item difficulty, and study strategies. Learner control of these components has been shown to significantly impact the time learners spend on a CAI lesson (Ross & Rakow, 1981), their performance (Avner, Moore, & Smith, 1980), and their continuing motivation to complete CAI tasks (Kinzie & Sullivan, 1989). This indicates that learner vs. computer control may be an important variable in the design of CAI. Despite this, empirical research has not led to useful prescriptions that specify which aspects of CAI should be controlled by the student and which should be controlled by the computer to produce the most effective instruction (Goetzfried & Hannafin, 1985; Klein, 1988). This paper reports the results of research on learner vs. computer control in dynamic simulation-based CAI. The end goal of the research is to advance prescriptions which will help instructional developers in designing effective CAI of this nature.

In certain dynamic tasks that require critical decisions to be made based on information presented in displays, speed can be equally as important as accuracy (Schneider, 1985). For example, pilots must constantly interpret information from different displays, make decisions based on their interpretations and follow through with actions to successfully control their aircraft. Unlike measures of performance in classroom settings (e. g., grading methods for academic tests), speed and accuracy are measured on a continuum with no clear upper or lower bounds. Less error and higher rates of speed indicate progress toward mastery. Such skills often require hours of practice and the actual technical apparatus student pilots are being trained to use is expensive. Also, flaws in performance during the operation of a real aircraft can be dangerous. Therefore, CAI is used to simulate instrument displays and provide a means for student pilots to perfect their skills in advance of training in an aircraft. This type of CAI is referred to as instructional simulation. Little research has been conducted with this type of CAI. Reigeluth and Schwartz (1989) have indicated that more empirical data is needed to develop prescriptions that will lead to effective instructional simulation.

One method of motivating learners to increase their rate of speed and degree of accuracy when

performing a dynamic task is to provide higher "levels of challenge" as their performance improves. This is a strategy that has been described as one of the most motivating aspects of computer games (Malone, 1981). Challenge can be increased or decreased by changing the criterion by which learners are given points for good performance. For example, a low challenge level can be defined as follows: 10 points are added to the learner's score for performing a task within 30 seconds, but these points will be subtracted if the learner exceeds this time limit. A high level of challenge for the same task would be produced by reducing the time limit to 15 seconds and increasing the number of points (to be gained or lost) to 100. Instructional simulations can be designed to either allow learners to control level of challenge, or challenge can be controlled by the program as a function of the learner's performance. Klein (1988) states that "...learners may not be the best judges when given control over item difficulty" (p. 25). They tend to choose too high or too low a challenge level for their current level of mastery.

Johansen and Tennyson (1983) argue that learners should be provided with information about their performance during a practice activity. They found that learners achieved more during a CAI lesson when given ongoing information on their degree of mastery of the learning objectives. Tennyson (1980) demonstrated that subjects performed better and completed instructional objectives in less time when using CAI that provided advice and allowed control over instructional components. In general, Tennyson and associates have shown that learner control features alone are not particularly effective, but if CAI provides useful advice throughout the learning activity that is relevant to the criterion task, learner control features can increase the efficiency of the instruction.

Despite the findings that learner control combined with advice can be an effective instructional component of CAI, most CAI research has been restricted to the acquisition of skills involving declarative and conceptual knowledge. The majority of CAI programs deliver content material in the form of verbal information, and students demonstrate mastery of the objectives by choosing answers to multiple-choice questions or by responding to questions with short definitions or descriptions. However, acquiring the skill of making decisions based on information from a dynamic visual display is quite different. Instead of studying a volume of text containing a variety of facts

and concepts and attempting to understand and remember the information, mastering skills for interpreting complex instrument displays requires hours of practice on the same basic task. For example, a student pilot must learn to integrate text, digital, symbolic, and spatial information in a single visual display. A decision must then be made based on this information, and the decision is acted on by executing a physical task (e. g., adjust the side-stick controller) to control the aircraft. Such a task must be executed with a high degree of speed and accuracy. Developing skills of this nature involves perceptual, motor, and cognitive ability and may require several hundred practice attempts across a variety of instrument settings. The experiment described below was conducted to examine the effects of learner control over level of challenge with and without advisement. Further, it examines learners' use of control features and their effects on performance and retention of skill for interpreting a complex visual display.

Method

Participants

Subjects were 78 undergraduates enrolled in the same course in the College of Education at a large public university in the Southwestern United States. They participated in the experiment for partial course credit. Performance data was collected from 12 pre-experimental subjects (four per treatment). The remaining 66, 12 males and 52 females, participated in the experiment. This male to female ratio is common for the college.

CAI Program

A CAI program, entitled HUD JR, was developed at AFHRL to conduct the research. HUD JR simulates part of a cockpit display called the Head-Up Display (HUD) and teaches subjects how to interpret its digital and symbolic information. One of the functions of the HUD is to provide radar-generated information on the position of other aircraft. This information is displayed as a set of numbers and symbols that must be interpreted by a pilot to determine location and heading of a target aircraft.

Procedure

The experiment was a two variable mixed design with repeated measures on test occasion. It had three levels of learner control, learner control with advisement (LCA), learner control without advisement (LC), and computer control (CC) by two levels of test occasion, immediate vs. seven day delayed. Three treatment groups were prepared by loading one of three versions of HUD JR on each computer in a microcomputer

laboratory. Data from the pre-experimental subjects was used to develop levels of challenge for speed and accuracy. Subjects were randomly assigned in about equal numbers to treatments based on the order they arrived at the computer laboratory. Six groups consisting of six to 20 subjects, equally distributed across the three treatments, completed two experimental sessions. In the first session, subjects completed a short lesson and skill test for using the Macintosh mouse, a lesson on interpreting the HUD, a 75-trial practice exercise for interpreting the HUD, a 25-trial test for locating targets with the HUD, and a questionnaire, all of which were delivered on the Macintosh II computer. The mouse skill test was used to measure subjects' initial ability for moving an icon with the mouse. Subjects were urged to pay close attention to the visual and verbal feedback provided during practice and use it to help them improve their performance. During the lesson, they were frequently reminded that speed and accuracy are equally important. The first session lasted about two hours. Subjects were instructed not to discuss the experimental procedures or the materials among themselves or with their classmates prior to the final session. The second session was held exactly one week later. Subjects spent about 10 minutes completing a second 25-trial test for locating targets with the HUD. After all subjects had completed both sessions, they were debriefed and provided with feedback on their performance. The data for five subjects was eliminated from the analyses, four due to technical problems with the software and one because of failure to complete the delayed test.

Materials

The experimental materials consist of five computer programs that: (1) taught subjects how to use a mouse to manipulate an icon on the CRT; (2) taught the basic knowledge and skills required for interpreting the HUD and locating targets; (3) provided practice and feedback for the target-location task; (4) delivered a posttest for target location; and (5) delivered a questionnaire to record subjects' attitudes and judgments about the learning experience. The programs recorded various behavioral data (e. g., time on task and accuracy of response) which was stored on disk in a standard text format.

The instruction and content material for HUD JR was validated in two ways. First, the basic target-location task was patterned after previous CAI programs developed at AFHRL (Lahey & Boyer, 1990). The earlier programs were completed following a task analysis of

the target-location task and interviews with student and instructor pilots. Second, subject matter experts reviewed HUD JR and provided comments that were used to guide revisions prior to the experiment.

Learners are taught to read and interpret three types of information displayed on the HUD as shown in Figure 1: range (distance to the target aircraft displayed as a number from 15 to 40 miles), azimuth (degrees of the target to the left or right of the pilot's heading indicated as an arrow pointing to the right or left and a number from 0 to 60), and aspect (angle from 0 to 359 degrees used to identify heading of the target and displayed as a pointer located on the perimeter of a circle).

Please insert Figure 1 about here.

During practice and test activities, HUD JR simultaneously presents values for each of the three types of information producing a variety of targets, none of which are repeated.

The target-location task requires learners to interpret the information displayed in the HUD and place the "Locator" icon (resembling an aircraft) at the correct position in the "Overhead," an overhead view of the pilot's aircraft and surrounding air space (Figure 1). After positioning the Locator, the subject saw (1) the target (icon showing the position where the subject should have placed the Locator); (2) the "challenge meters;" and (3) the number of points gained or lost for speed and accuracy (Figure 2).

Please insert Figure 2 about here.

The learner evaluates his/her performance by comparing the position of the Locator with the position of the target and by examining the number of points gained or lost. The number of points gained or lost was a function of the learner's speed, accuracy, and current challenge level.

Three experimental treatments were created by developing different versions of the HUD JR program. The LC treatment allowed the learner to set levels of challenge for speed and accuracy by moving the pointers of the challenge meters up or down the scales with the mouse. The LCA treatment gave subjects the same control but also displayed advice (e. g., "set the speed challenge to 35") based on their cumulative performance over the most recent five trials. In the CC treatment the challenge levels were automatically set and learners could not alter challenge for speed or

accuracy. The target-location task was the same as in practice for both immediate and delayed tests except that no visual (appearance of the target) or verbal (points) feedback was provided. The subjects responded to bipolar attitude statements about their learning experience and answered questions about their performance after the immediate test by moving a pointer along a linear scale (Figure 3).

Please insert Figure 3 about here.

Criterion Measures

Subjects' performance consisted of their speed and accuracy for locating targets. Additional data was collected to further describe subjects' behavior during the learning activities.

Subjects' response speed for locating a target included the time interval from the onset of the information displayed in the HUD to the time the subject clicked on the Continue button. A subject's accuracy was judged on three dimensions: range error (in centimeters), azimuth error (in degrees), and heading error (in degrees).

Responses to attitude statements and questions were recorded as the position of a pointer along a linear scale. Subjects were asked to estimate aspects of their performance such as time on task and number of targets located before becoming fatigued.

Data Analysis

Multivariate analyses of variance (MANOVA) were conducted on dependent measures of performance and on-task behavior. Additionally, univariate tests were conducted on individual variables. Initial task time for positioning the icon with the mouse was used as a covariate for multivariate and univariate tests when it showed a significant correlation with the dependent variable of interest. The significance level was set at $p<.05$ for all multivariate and univariate tests.

Results

Performance on Immediate and Delayed Tests

Table 1 displays the means for each of the dependent variables by treatment group. Smaller means equate to superior performance since they indicate greater speed or less error.

Please insert Table 1 about here.

The MANOVA did not reveal a significant main effect for learner control treatments ($F(8,108)=0.62$, $p>.05$), but a main effect did occur for test occasion ($F(4,55)=6.02$, $p<.001$). The means in Table 1 reflect

this increase in task time and error from the immediate to the delayed test across all four dependent measures.

Univariate analyses revealed an interaction for treatment by test occasion ($F(2,58)=4.95$, $p<.05$). LL subjects performed the target-location task more quickly on the immediate test than the CC or LCA subjects ($M=12.9$ vs. $M=14.1$ and $M=13.7$ seconds) but performed closer to the same rate on the delayed test ($M=14.6$ vs. $M=14.4$ and $M=15.7$). None of the other performance variables showed significant differences in performance as a function of the learner control treatments or test occasion.

On-Task Behavior

Because the difference on task time between the two tests was most apparent for the LC and LCA treatments, a second MANOVA was conducted on the challenge levels and points gained and lost during the practice activity for these two groups. It revealed a significant multivariate effect for treatment ($F(2,38)=4.48$, $p<.05$). The univariate tests showed that the LCA subjects set a higher challenge level for accuracy than the LC subjects ($M=60.2$ vs. $M=41.3$, $F(1,39)=8.91$, $p<.01$) but gained less accuracy points ($M=38.5$ vs. $M=56.7$, $F(1,39)=4.92$, $p<.05$).

A third MANOVA was conducted on the LCA and LC treatment groups for the number of changes subjects made in level of challenge for speed and accuracy. It revealed a significant multivariate effect for treatment ($F(4,36)=5.61$, $p<.001$). Univariate tests indicated that the LCA subjects changed the level of challenge more frequently than did subjects in the LC group: $M=14.1$ vs. $M=6.4$, $F(1,39)=23.4$, $p<.001$ for accuracy challenge and $M=10.0$ vs. $M=5.3$, $F(1,39)=10.71$, $p<.01$ for speed challenge.

To determine to what degree subjects in the LCA group followed the challenge advice delivered every five trials, the probability that subjects adjusted the level as prescribed was computed. This was done for every occurrence of advice where the current level of challenge was at least five units higher or lower than the prescribed level. The probability that advice for speed was followed (to within five units of the prescribed level) was $p=0.75$ and was $p=0.68$ for accuracy.

Responses on Questionnaire

Responses to some of the questions about the learning experience were useful in describing behavior. There was no significant effects for treatments for judgments subjects made on "...number of targets you located before becoming tired of the task" or for the attitude statement, "I enjoyed locating targets with

the HUD Simulator." Means for these two items were computed across treatments. The mean for number of targets located before subjects begin to feel tired of the task was 31. The mean for the attitude statement was 0.30 which inferred that subjects tended to enjoy the task. The response range for attitude statements was -1.0 (complete disagreement) to 1.0 (complete agreement). Finally, there was a significant effect ($p<.01$) for treatments for the attitude statement, "I would want the level of challenge for speed controlled by the computer," M=-0.21, 0.20, and -0.23 for LCA, CC, and LC treatments respectively. This inferred that learner control was favorable to subjects in groups that employed learner control, but computer control was favorable to subjects in the computer control treatment. A similar statement for control of accuracy challenge did not reach a level of significance, M=-0.05, 0.11, and -0.19 for LCA, CC, and LC respectively.

Discussion

Because the learner control treatments did not permanently effect performance, it is assumed that learner control did not change subjects' ability to learn the task. Detecting performance effects of learner control for this type of task may require multiple practice sessions. Cronbach and Snow (1977) intimated that 10 or more separate interactive sessions may be necessary to acquaint students with an innovative instructional treatment. Perhaps two hours is not enough to have a variable as complex as learner control show a stable effect. Schneider (1985) indicates that students learning a complex, dynamic task show very slow acquisition rates, and that initial performance of such tasks is highly unstable. However, some aspects of subjects' behavior during practice and the immediate test may be useful to instructional developers and future experiments on learner control.

The major contributor to the treatment by test occasion interaction appeared to be the LC treatment. Subjects in this group executed the target location task more quickly during the immediate test, but performed at about the same rate during the delayed test a week later. This may have resulted from LC subjects setting the challenge level lower for accuracy than LCA subjects and LC subjects receiving more accuracy points during practice. By setting the accuracy challenge at a lower level, LC subjects seldom received negative feedback, i. e., points being subtracted from their score. The program was designed to provide more points possible when challenge levels were set higher but this also created a greater risk of

losing points. For example, a subject could gain 100 accuracy points for locating a target at the highest accuracy challenge level, but the response had to be extremely accurate. If it was not, the subject risked losing 100 points. Conversely, only 10 accuracy points could be gained at the lowest level, but the response did not have to be nearly as accurate to do so. Having set the challenge for accuracy at higher levels, LCA subjects lost more points than LC subjects and probably became more cautious, and therefore, slower. LC subjects continued to respond more quickly during the immediate test, but this increased rate of speed did not continue during the delayed test.

The fact that points gained and lost appeared to change subjects' behavior during practice and the immediate test has some implications for instructional design. If students' performance is reflected in a score that is continuously updated and displayed during a practice activity, it may be possible to focus students' attention on particular aspects of the task (e. g., speed). The criterion used to keep score could be adjusted to shift each student's emphasis from speed to accuracy or vice versa as needed.

Subjects in the LCA group likely changed the levels of challenge for speed and accuracy more often than LC subjects because of the additional advice given during practice. Although all subjects received cumulative information about their performance every five trials, only LCA subjects were reminded to adjust the challenge levels every five-trial block. Both LC and LCA subjects were taught how to change level of challenge during the introduction to the practice activity and urged to adjust challenge as they practiced, but LC subject may have forgotten about this control feature. It appears that learners need to be reminded about instructional control features frequently during a lesson. If students are not prompted to use such features, they may forget the controls exist or think of them as unimportant to the task at hand. We suspect that this would be especially likely to occur when learners are engaged in a complex, fast-moving task where part of the criterion performance is to respond as quickly as possible. Even tentative conclusions about the effect of learner control on challenge rests on the assumption that learners paid attention to and were concerned with points they received for speed and accuracy. The effects could be verified by offering subjects monetary rewards for points.

It was surprising that subjects in the computer control treatment tended to favor the control of speed

by the computer, while subjects in the two learner control treatments favored learner control of speed. This may be due to subjects transferring positive feelings about the overall learning experience to the CAI. It is possible that they favored the form of instructional control they were given simply because they found the task to be enjoyable or, at least, stimulating.

The results of this experiment will be used to improve future experiments on learner control of challenge and learner control over other instructional components. Descriptive information, such as number of targets subjects located before becoming tired of the task, will help shape future research that uses the same or similar tasks as a learning outcome. The difference between subjects performance across the seven-day delay shows the value of using delayed tests to determine if treatments have influenced learning or temporarily altered subjects' performance.

Researchers who plan to investigate the acquisition of complex of motor, perceptual, and cognitive skills may wish to consider conducting at least two experiments. The first can be very useful in providing important descriptive information that may lead to an increase in power of succeeding experimental designs. It may also be helpful to employ multiple practice sessions because complex, dynamic skills can require more time to mature than learning outcomes that are frequently encountered in academic settings.

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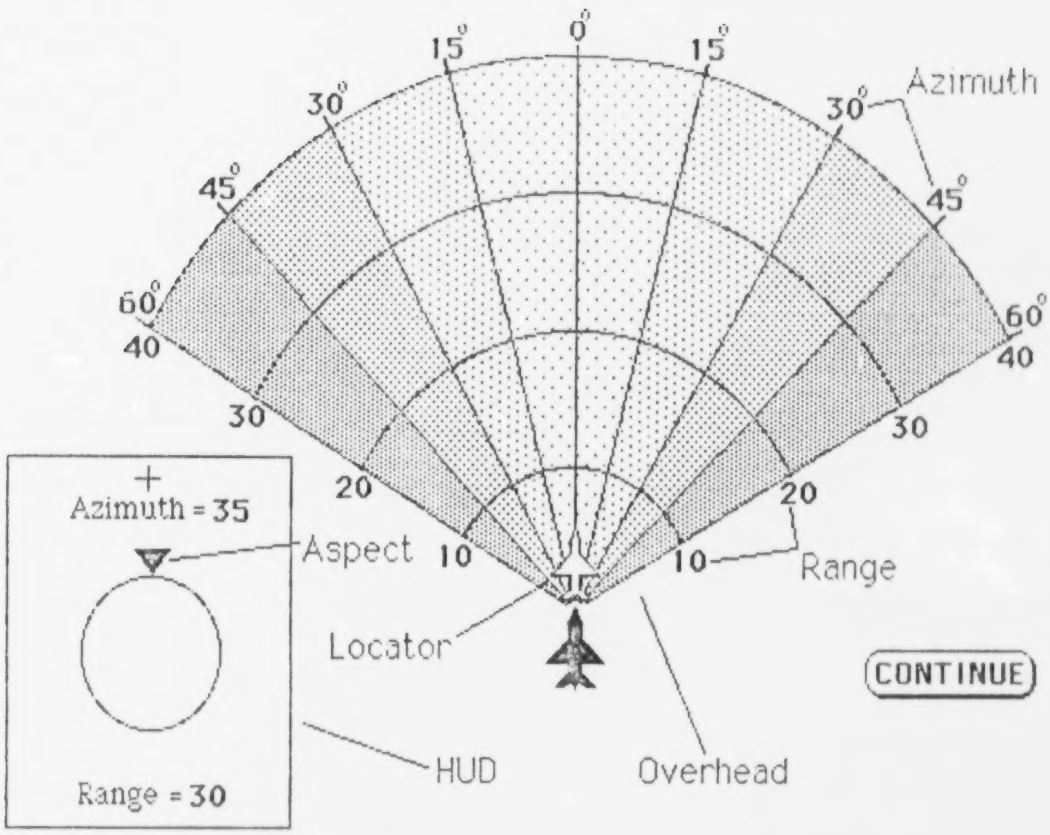
Table 1
Means: Task Time: (in seconds), Range Error (in centimeters), Azimuth and Heading Error (in degrees)

Group	Immediate Test				Delayed Test			
	Time	Rng.	Azi.	Hd.	Time	Rng.	Azi.	Hd.
LCA								
M	13.7	0.16	1.8	25.8	15.7	0.21	2.4	33.5
SD	2.76	0.03	0.38	9.42	2.92	0.15	2.07	18.56
CC								
M	14.1	0.15	1.7	23.9	14.4	0.20	2.5	32.1
SD	3.05	0.05	0.56	9.24	3.72	0.12	1.40	21.08
LC								
M	12.9	0.17	1.8	24.6	14.6	0.22	2.7	29.0
SD	2.26	0.05	0.52	7.29	2.20	0.17	2.45	14.56

Note. Lower values indicate better performance.
LCA = learner control with advisement
CC = computer control
LC = learner control without advisement

Figure Caption

Figure 1. Head-Up Display (HUD), Overhead, and target-location icons and information.
Figure 2. Points for speed and accuracy and challenge level meters.
Figure 3. Method used for answering questions and responding to bipolar attitude statements.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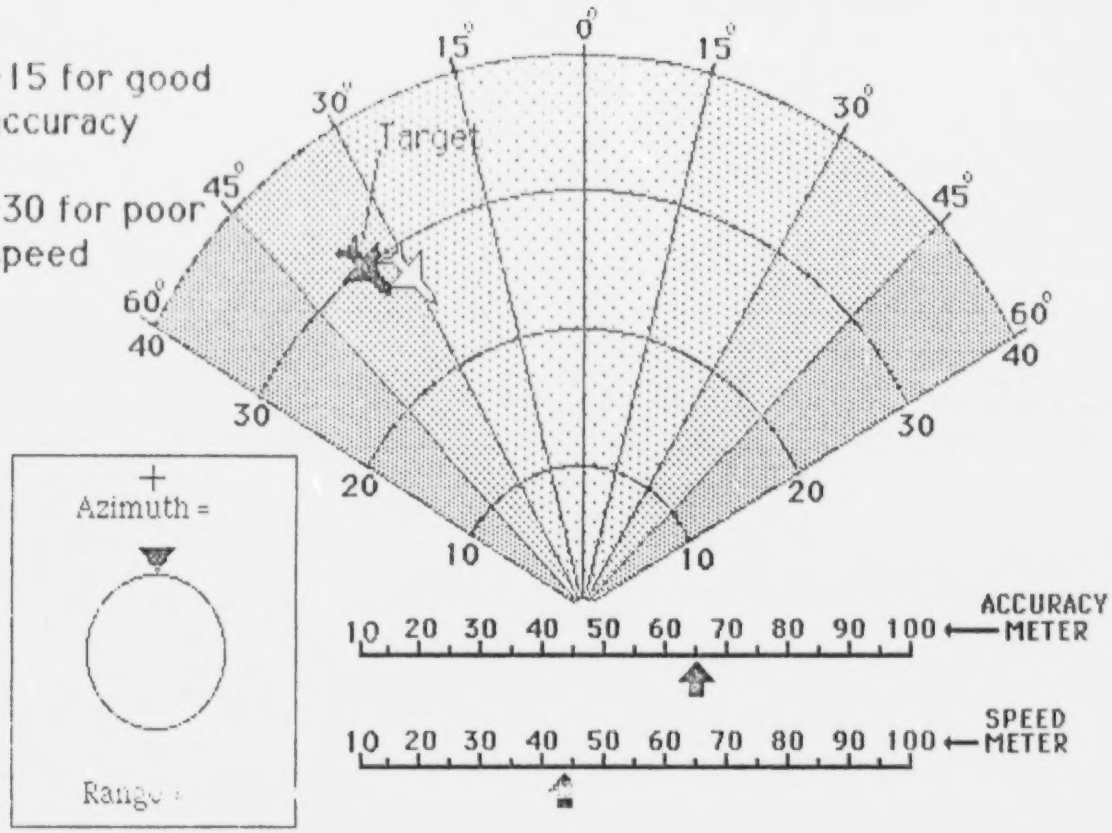
HUD
Overhead

+15 for good accuracy

-30 for poor speed



I enjoyed locating targets with the HUD Simulator.